The Establishment of Bracken Following Fire in Tropical Habitats

STEPHEN R. GLIESSMAN*

The spread of Bracken, *Pteridium aquilinum* (L.) Kuhn, as a vigorous and dominant weed is well recognized in many vegetation types throughout the world (see Braid, 1959, for a review). It has been demonstrated that this dominance is a consequence of the fern's rapid extension of underground stems and abundant vegetative reproduction (Watt, 1943, 1947), its strong allelopathic potential (Gliessman & Muller, 1972), and its resistance to fire (Vogl, 1964). Very little attention has been directed to spore germination, gametophyte formation, and sporeling establishment in relation to the dominance of Bracken.

Bracken is capable of producing large numbers of spores on each frond, and the time of spore release can extend through much of the growing season (Conway, 1957). In temperate regions, however, most spore dispersal takes place during the drier part of the year or just before the winter begins, times of the year that do not particularly favor sporeling establishment. This would explain, at least in part, reports of the small number of Bracken sporelings which become established under natural field conditions (Conway, 1953). In the tropics, where conditions of temperature and humidity are much more equable, such climatic control of spore germination and early growth presumably is less important. I have observed continual growth of new Bracken fronds throughout the year in several locations in Costa Rica (Gliessman, 1976). It is possible, then, that spore release is not restricted to a certain period, as it is in temperate regions (Conway, 1957), but may be much more haphazard over the entire year. Thus, a constant source of spores could be available for any potentially habitable area.

Observations were made in the field in Costa Rica to determine the conditions under which Bracken sporelings become established, which has possible implications for Bracken control. In Costa Rica, Bracken is encountered frequently from just above sea level on well-drained soils up to more than 3000 m elevation. As in other areas of the tropics (Richards, 1966, pp. 391-399), Bracken most often forms a type of deflected succession in regions formerly covered with dense, tropical forest. These are areas that have an annual rainfall in excess of 2500 mm, the majority of which is concentrated in the wet season that extends from mid-May to late December. Due to frequent cloud cover (especially at higher elevations) and the occurrence of sporadic rainfall even in the dry season, humidity at the soil level is quite favorable for sporeling establishment all year around.

The pattern of land use in this part of the tropics appears to lend itself quite well to the establishment of Bracken. Most forest clearing, using the well known system of "slash and burn," takes place towards the end of the wet season (December) until late in the dry season (late April). The felled material is allowed to dry as much as possible. Before the more frequent rainfall begins in early May, the slash is burned. As a consequence, when the wet season rains begin in earnest,

*Departmento de Ecología, Rama de Biología, Colegio Superior de Agricultura Tropical, Apartado 24, H. Cárdenas, Tabasco, México.

the conditions that are encountered following the fire very closely approximate the ideal conditions described by Conway (1949) for sporeling establishment and young sporophyte growth. She demonstrated that spore germination took place very soon after release from the fronds, and that it was best on soils with an alkaline reaction (pH 7.0-7.7), especially on sterilized soils.

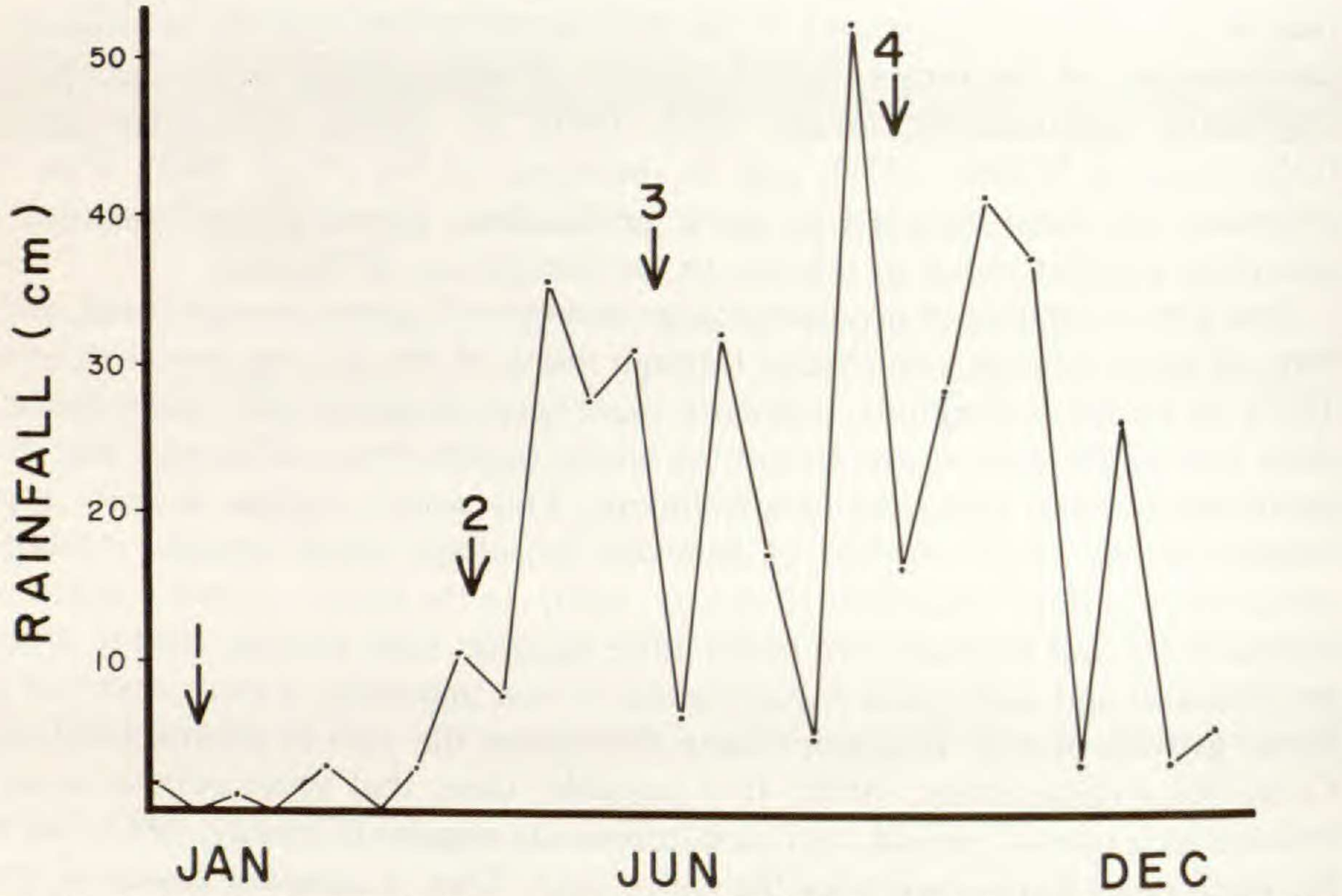

FIG. 1. Biweekly totals of rainfalls at Finca Loma Linda in 1973. 1 = initiation of forest clearing; 2 = widespread burning of slash; 3 = widespread occurrence of gametophytes; 4 = establishment of young sporophytes.

On the western boundary of Finca Loma Linda (1300 m elevation) approximately 2 km south of Cañas Gordas, Coto Brus, in southern Costa Rica, a section of montane moist tropical forest was cut beginning in the early dry season (*Fig. 1*). In late April, the slash was burned. Immediately following the first heavy rains two weeks later, I performed soil pH analyses of the upper 5 cm of soil, including the ash layer. Readings ranged from pH 7.0 to 8.0, there being a positive correlation between higher pH and greater ash depth. The ashes were compacted into a dense layer on the soil surface by the rains and ranged from 3 to 11 mm deep. Low areas and depressions where rainwater had accumulated had the greatest ash depth. In a part of the deforested area that escaped burning, I found pH readings ranging from 5.2 to 5.8, the soil surface being covered with a mat of organic matter composed of humus and intact plant detritus up to 3 cm thick. Thus, only on the burned areas after the onset of the wet season did conditions combining a high pH and a probable reduction in microbiotic diversity exist which were ideal for sporeling development.

Four weeks after the soil pH analyses were completed, on 7 June 1973, I made direct counts of gametophytes easily visible with the naked eye in ten randomly

placed, 10 cm² plots. I found (*Table 1*) that a considerable number of well-formed Bracken gametophytes already had become established. Coverage of the soil surface by the developing gametophytes was practically complete. Much closer inspection would probably have revealed more recently germinated spores and very young gametophytes. Nevertheless, the quantities observed are much higher than any others that have been reported in the literature for observations made under natural field conditions (Whyte, 1930; Conway, 1953). Careful inspection of those cutover areas that escaped burning failed to reveal any Bracken gametophyte establishment.

On 18 August 1973, I reexamined the same sites for the establishment of young sporophytes. Of the gametophytes originally observed, approximately 20% had formed sporophytes (*Table 1*). The number may actually be less than 20%, because individual gametophytes were not marked and new gametophytes could have developed during the time following the initial observations. Still, the numbers of sporophytes in such small areas is impressive.

TABLE 1. NUMBERS OF BRACKEN GAMETOPHYTES IN 10 cm² SAMPLES TAKEN 4 WEEKS AFTER SOIL pH ANALYSIS AND SPOROPHYTE ESTABLISHMENT 10 WEEKS LATER.

Sample no.	*No. gametophytes*	*No. sporophytes*
1	115	27
2	85	15
3	68	13
4	127	16
5	94	23
6	73	14
7	78	17
9	96	19
10	84	10
Average	92.2	16.9

On more favorable sites (e.g., near downed logs or burned-out stumps) several plants had produced as many as six fronds, some up to 25 cm long, but the majority had two or three fronds with an average length of 5–10 cm. If we consider that at the time of these observations there remained at least 3.5 months of additional frequent rainfall and abundant soil humidity, the growth rates of which the young bracken sporophytes are capable (Conway, 1949) would certainly allow the plants to become well established before the more difficult conditions of the following dry season arrived.

The menace posed by the vegetative spread of Bracken in many parts of the world, including the tropics, is well known (Page, 1976). The capability of Bracken to occupy large tracts of land with former agricultural value has long been observed in Costa Rica (Standley, 1937, p. 29). Once having become established, the fern is very difficult to eradicate manually or mechanically, and only the widespread application of new chemical fernicides offers control (Martin, 1976). Because of the delicate nature of gametophytes in general and the rather narrow tolerance for environmental stress of the germinating spores, I believe it would be easier to prevent the establishment of Bracken than to remove it following its introduction.

During the early stages of development, especially initial establishment, individual plants are most susceptible to adverse environmental factors. In the case of Bracken, understanding that the optimum conditions for sporeling establishment are very similar to those encountered following fire, management practices that avoid these conditions would best prevent its introduction. In the tropics, where conditions of temperature and humidity are very favorable for gametophyte establishment and growth all year around, control of soil characteristics such as pH and microbial diversity might be a positive preventive. Fire should not be used in regions especially susceptible to Bracken infestation or close to areas already dominated by the fern after the original vegetation has been cleared. If high labor cost or physical obstruction to planting caused by the downed slash makes the use of fire necessary, it could be applied only if the slash were gathered in mounds, burned, and then the concentrated ash carefully observed and clinically treated or repeatedly disturbed if gametophytes or young sporophytes appear.

Bracken rapidly takes advantage of conditions created after fire in the tropics. Young sporophytes become established in a very short time in areas where Bracken did not exist before. The widespread use of fire in the tropics thus favors an ever-increasing spread of Bracken. Observations on the establishment of sporelings following fire may provide the necessary tools for preventing dominance by this fern.

LITERATURE CITED

BRAID, K. M. 1959. Bracken: a review of the literature. Hurley: Commonwealth Agricultural Bureaux.

CONWAY, E. 1949. The autecology of bracken (Pteridium aquilinum (L.) Kuhn): the germination of the spore and the development of the prothallus and the young sporophyte. Proc. Roy. Soc. Edinburgh. **63:** 325-343.

———. 1953. Spore and sporeling survival in bracken (Pteridium aquilinum (L.) Kuhn). J. Ecol. **41:** 289-294.

———. 1957. Spore production in bracken (Pteridium aquilinum (L.) Kuhn). J. Ecol. **45:** 273-284.

GLIESSMAN, S.R. 1976. Allelopathy in a broad spectrum of environments as illustrated by bracken. Bot. J. Linnean Soc. **73:** 95-104.

———, and C. H. MULLER. 1972. The phytotoxic potential of bracken (Pteridium aquilinum (L.) Kuhn). Madroño **21:** 299-304.

MARTIN, D. J. 1976. Control of bracken. Bot. J. Linn. Soc. **73:** 241-246.

PAGE, C. N. 1976. The taxonomy and phytogeography of bracken—a review. Bot. J. Linn. Soc. **73:** 1-34.

RICHARDS, P. W. 1966. The Tropical Rain Forest, rev. ed. Cambridge University Press, Cambridge.

STANDLEY, P. C. 1937. Flora of Costa Rica. Part I. Field Mus. Nat. Hist., Bot. Ser. **18:** 1-398.

VOGL, R. J. 1964. The effects of fire on the vegetational composition of bracken-grasslands. Wisconsin Acad. Sci. Arts Lett. **53:** 67-82.

WATT, A. S. 1943. Contributions to the ecology of bracken (Pteridium aquilinum (L.) Kuhn). II. The frond and the plant. New Phytol. **42:** 103-126.

———. 1947. Contributions to the ecology of bracken (Pteridium aquilinum (L.) Kuhn). IV. The structure of the community. New Phytol. **46:** 97-121.

WHYTE, J. H. 1930. The spread of bracken by spores. Trans. Bot. Soc. Edinburgh **30:** 209-211.